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Research paper

Secular trends in fall-related hospitalizations in adolescents, youth and adults: a population-based study

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ABSTRACT

Background: Falls are one of the major causes of injury globally. However, there is a lack of population-based studies on falls among adolescents, young and middle-aged adults. We therefore aimed to conduct a large-scale population study on the secular trend in incidence of fall-related hospitalization.

Methods: A population-wide electronic database, Hong Kong's Clinical Data Analysis and Reporting System (CDARS), was used in this retrospective cohort study. Patients aged≥10, hospitalized with diagnosis of accidental falls (ICD-9-CM E880-E888) from 2005-2018, were included. Outcome measures included the number, age- and sex-standardized incidence rate of fall-related hospital admissions, their length of stay (LOS) and 1-year all-cause mortality. Linear regression and average annual percentage change (AAPC) using joinpoint regression were computed for trend analysis.

Findings: From 2005 to 2018, a total of 336,439 patients aged≥10 were identified with fall-related hospitalization. Among these fall patients, 33.7% occurred at age<60. The number of fall-related hospital admissions episodes increased significantly by 83.7% during the study period. The standardized incidence rate of falls per 1000 person-years increased from 3.67 (95% CI 3.62-3.72) in 2005 to 4.79 (95% CI 4.74-4.84) in 2018. Although the total hospitalized bed-days increased from 178,723 days in 2005, to 299,273 days in 2018 (+67.5%,p<.0001), the median length of stay per episode of falls decreased from 4.90 days to 3.79 days (p<.0001).

Interpretation: Continuous increase in the incidence of fall-related hospitalization in people aged≥10 was observed. This suggested that falls are a public health issue in all ages. Further studies on the differences in the underlying risk factors and comorbidities between younger and older fall patients are warranted.

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Research in context

Evidence before this study

We searched PubMed for studies between Jan 1, 2010, and Dec 31, 2020, using search terms ((accidental falls[MeSH]) OR "unintentional fall") AND (young adult[MeSH]) AND ((hospitalization[MeSH]) OR (emergency service[MeSH])). We reviewed studies that investigated or mentioned fall-related injuries among non-geriatric population. Of the 276 studies reviewed, 11 of them discussed on the incidence of falls among individuals of all age, or stratified the study population into younger and older population. However, most of the studies were conducted in earlier years, or did not comprise analysis of secular trend.

Added value of this study

This population-based cohort study identified more than 300,000 patients with fall-related hospitalization in Hong Kong from 2005 to 2018 using a population-based electronic medical database involving approximately 7 million population. This study showed significant increase in the incidence of fall-related hospitalization and total number of consequent hospital bed-days among most strata by sex and age groups. To our knowledge, this is the first population-based cohort study comparing the secular trend of incidence of fall-related hospitalization in different age groups. This study not only showed consistent results with previous studies on the increase of fall-related hospitalization among the geriatric population, but also among the younger population. Indeed, approximately one-third of the fall-related hospitalization records were contributed by patients younger than 60. More importantly, despite recent effort put into various fall prevention programs and clinics, no significant deviation in the increasing trend of incidence was observed.

Implications of all the available evidence

This study suggested serious research gap on the potential impact of falls among non-geriatric population on the public healthcare system. Fall prevention measures should not be limited to the older population, but should also be extended to the younger population. Future research should also examine how the risk factors of falls differ among sex and various age groups, as well as how current fall prevention programs could be tailor-made to different target population.

1. Introduction

Accidental falls are the leading cause of injury worldwide which is associated with increased risk of severe injury, hospitalization, institutionalization, and even death, especially in the elderly. In view of the rapidly expanding elderly population worldwide, the World Health Organization (WHO) commented that "the economic and societal burden of falls will increase by epidemic proportions in all parts of the world over the next few decades" in their global report on fall prevention published in 2007. [1] More recently, the Global Burden of Disease Study 2017 (GBD 2017) also released a report on the incidence and mortality of fall. Although it was a study that modelled the prevalence based on data from various sources, it reported that the age-standardized incidence of falls was 2,238 per 100,000 in 2017. [2] More importantly, the study showed that falls were in fact the 18th leading cause of age-standardized rates of disability-adjusted life years in 2017, which was higher than other commonly known chronic conditions including chronic kidney disease. This suggested that in spite of the emergence of many other chronic diseases, falls still remain a leading cause of non-fatal health loss.

Although it is commonly perceived that the older population (people aged 60 or above) is more susceptible to accidental falls, falls have indeed been increasingly seen in the younger population. This could be attributed to increasing cell phone use and engagement in dangerous activities, [3] like practicing dangerous parkour, [4] or taking part in various viral challenges, such as skull-breaker challenge and [4, 5] stand up challenge, [4] which have been widely reported by the media globally. [4-6] Thus, monitoring the trends of accidental falls in all ages, including the younger population, is urgently needed. However, discussion on the secular trend of fall-related injuries in the younger population was limited, with only brief mentions and little elaboration in GBD2017 and the U.S. Web-based Injury Statistics Query and Reporting System. There was also a lack of studies on falls among young adults in Hong Kong.

Reporting the incidence and trend of severe accidental falls, especially those required extensive medical care such as fall-related hospitalization, using population-based database is critical for public health surveillance, which may subsequently lead to the development of relevant policy in prevention and intervention. In view of the lack of comprehensive data on fall-related hospitalization, we aim to report the trend of incidence of fall-related hospitalization and its related outcomes in people aged 10 or above between 2005 and 2018 in Hong Kong, using a population-based electronic medical database involving approximately 7 million population.

2. Methods

2.1. Data source

Data of the current study was from the electronic medical records from the Clinical Data Analysis and Reporting System (CDARS), a population-wide electronic database of Hong Kong. Hong Kong is a special administrative region (HKSAR) of China with a population size of 7.44 million. The CDARS is a database managed by the Hong Kong Hospital Authority, which is a public healthcare statuary body that manages all 43 public hospitals and institutions, as well as 122 out-patient clinics located within Hong Kong. Data from the participating institutions are automatically uploaded to the data warehouse and sent to the CDARS system for report, audit, and research purposes. [7] CDARS accounts for >84% records of fall-related hospitalization in Hong Kong. [8] Clinical data in CDARS included diagnosis, prescription and procedural records from all inpatient and outpatient visits to facilities under the Hospital Authority since 1995. All coding were made by the hospital physicians. Both chief complaints and other related diagnosis included injuries records were coded. The comprehensive CDARS data has been used in high-quality population-based studies [9,10], with similar results shown in post hoc analysis of randomized control studies [11,12].

2.2. Study design and participant

This is a retrospective cohort study, analyzing the hospitalization data of patients aged 10 years or above, who were admitted to hospital through the Accident & Emergency (A&E) Departments between January 1st 2005 and December 31st 2018, with a diagnosis code of accidental falls (International Classification of Disease, Ninth Revision [ICD-9] E880-E888). Hong Kong first adopted the electronic Clinical management System and the Clinical Data Analysis Reporting System (CDARS) in 2000, with the inclusion of electronic Patient Records (ePR) since 2002. [13] All records prior to 2000 were retrospectively input into the system based on paper records. However, the usual clinical practice, especially for A&E admission policies, was severely disrupted in 2003 due to the SARS outbreak. 2005 was therefore chosen as the cohort starting date in order to avoid fluctuations due to practice disruption. Hospitalization records from follow-up procedures and hospital transferal were excluded to avoid data duplication. All the records were

checked for any missing data or data discrepancies, and were removed from the cohort if there was any. Patients with missing demographic information were excluded (N=2). The study has been approved by the institutional review board of the University of Hong Kong and Hong Kong Hospital Authority (Reference Number: UW 19-798).

2.3. Statistical analysis

Descriptive statistics for the cohort were presented as mean ± standard deviation (SD) for continuous variables, and as number and percentages for categorical variables.

The primary outcome of interest was the incidence of fall-related hospitalization. The annual incidence rate of fall-related hospitalization was defined as the number of fall-related hospitalization episodes divided by the total population of the corresponding age group in each calendar year. A wash-out period of 90 days was used in defining episodes of falls, meaning that fall-related hospitalization records with admission date within 90 days after the previous discharge date would be considered as the same episode of fall-related hospitalization. Sensitivity analysis using a shorter wash-out period of 30 days and a longer wash-out period of 180 days were also conducted. The total population size was obtained from the data released by the Census and Statistics Department of the HKSAR government. [14] The Hong Kong population census is a population-based survey conducted by the Census and Statistics Department of the HKSAR Government. It covered all people who meet the definition of the Hong Kong Resident Population and reported the Hong Kong population on July 1st of each calendar year. The age- and sex-specific incidence rates were calculated in the following age groups: 10-19, 20-29, 30-39, 40-49, 50-59, and ≥60. The standardized incidence rate was computed by adjusting the crude incidence rate with the sex and age distribution of Hong Kong 2011 census population using direct standardization method. All incidence rates were presented per 1000 person-years.

The secondary outcome of interest of this study is length of stay (LOS) and 1-year all-cause mortality rate of hospitalized fall patients. The LOS was defined as the number of hospitalized bed-days from the date of admission to the date of discharge. The calculated LOS was further adjusted by removing overlapping periods between hospitalization records of the same patients due to intermittent transfer between hospitals for procedural purposes to avoid over-estimation. The overlapping period is usually within 1 day. The total LOS was defined as the total number of hospitalized bed-days among all the fall episodes per calendar year. The median LOS referred to the median length of stay of patient per episode of falls.

The 1-year all-cause mortality among fall patients was commonly used in various studies on falls and related injuries. [15-17] It was calculated based on the first fall-related hospitalization record of each patient. Patients with fall-related hospitalization record prior to the study period (n=5810) were excluded from the mortality analysis. Similar to incidence rate, age- and sex-specific 1-year all-cause mortality rate were calculated for the six age groups (10-19, 20-29, 30-39, 40-49, 50-59, and ≥60). 1-year all-cause mortality rate was defined as the number of fall patients who died within 1 year after the initial date of admission divided by the total number of fall patients. The standardized 1-year all-cause mortality rate was computed by adjusting the crude 1-year all-cause mortality rate with the sex and age distribution of fall patients in 2011 using direct standardization method. All mortality rates were presented per 1,000 fall patients.

2.3.1. Trend analysis

Linear Regression analysis between the study year and the rates were conducted to detect any linear trend in incidence rates, total LOS, median LOS and 1-year all-cause mortality rates in each age group and sex over the 14-year study period. Trends in incidence and mortality rates were also evaluated using joinpoint regression analysis (Joinpoint Regression Program, Version 4.0.4, May 2013; Statistical Methodology and Applications branch, Surveillance Research Program, National Cancer Institute) [18,19].

2.3.2. Clinical outcomes analysis

Fall-related clinical outcomes were defined as injuries that were coded during the hospitalization period of the falls. Severe injuries under investigation comprised head injuries [including fracture of skull (ICD-9 800-804) and intracranial injuries (ICD-9 850-859)], spinal injuries [including fracture of vertebral column (ICD-9 805-806) and spinal cord injury without evidence of spinal bond injury (ICD-9 952)], fracture of upper limb (ICD-9 810-819), fracture of lower limb (ICD-9 822-829), fracture of hip (ICD-9 820-821), fracture of trunk (ICD-9 807-809) and dislocation (ICD-9 830-839).

All data management and statistical analyses were performed using R version 3.6.3.

2.3.3. Role of funding source

Nil

3. Results

A total of 336,439 patients aged 10 or above were admitted into the hospital through the A&E department with a diagnosis of accidental falls from 2005 to 2018. Table 1 showed the basic demographic information of the cohort population. 184,907 (55.0%) of them were female. Among all the 389,614 fall-related episodes identified, 48,704 (14.5%) patients had more than one admission from 2005 to 2018. 258,196 (66.3%) admission occurred when the patients were ≥ 60 years old, while 131,418 (33.7%) occurred at the age between 10 and 59.

The total number of hospitalized episodes due to fall injuries increased by 83.7% from 20,720 in 2005 to 38,061 in 2018. The corresponding standardized incidence rate increased from 3.67 (95% CI 3.62-3.72) per 1000 person-years in 2005 to 4.79 (95% CI 4.74-4.84) per 1000 person-years in 2018 (Figure 1). Increasing trends were seen for most subgroups by age and sex (Table 2 and Figure 2), except for male between 20 and 29 years old. Sensitivity analysis using a shorter wash-out period of 30 days and a longer wash-out period of 180 days also demonstrated similar significant increase in incidence rate (Supplementary Tables 2 and 3).

Likewise, the total number of fall episodes with severe injuries (defined by the presence of head or spinal injuries, fractures or dislocations at the occurrence of falls) increased significantly by 59.0% from 18,387 in 2005 to 29,238 in 2018 ($p<.0001$). The corresponding standardized incidence rate increased from 3.25 (95% CI 3.20-3.30) per 1000 population in 2005 to 3.70 (95% CI 3.66-3.74) per 1000 population in 2018 in the whole population. Similar increase was observed in most subgroups, except in male aged between 20 and 29 (Table 3).

The total LOS of all fall episodes increased significantly by 67.5% from 178,723 days in 2005, to 299,273 days in 2018 ($p<.0001$) (Figure 2). Conversely, the median LOS per episode of falls decreased significantly from 4.90 days in 2005 to 3.79 days in 2018 ($p<.0001$) (Table 4), and this trend was seen for most subgroups by age and sex, except in the age group of 10-19, and female aged between 20-39.

The 1-year all-cause mortality increased significantly by 64.6% from 1,522 in 2005 to 2,505 in 2018 ($p<.0001$; AAPC +3.7% [95% CI +2.9% to +4.5%]; Supplementary Table 4). The corresponding standardized 1-year all-cause mortality rate decreased from 92.98 (95% CI 88.35-97.79) per 1000 fall patients in 2005 to 75.47 (95% CI 72.53-78.52) per 1000 fall patients in 2018. Similar decreasing

Table 1
Basic demographic characteristics of patients who were admitted to the hospital with unintentional falls in Hong Kong, 2005 – 2018

	Overall
Total number of patients	336439
Sex	
Female	184907 (55.0)
Male	151532 (45.0)
Age at first occurrence (mean (SD))	64.21 (22.91)
Total number of fall episodes	389614
Age groups (%)	
10 – 19	23899 (6.1)
20 – 29	15571 (4.0)
30 – 39	19202 (4.9)
40 – 49	27569 (7.1)
50 – 59	45177 (11.6)
≥ 60	258196 (66.3)
Serious injuries (head injuries, spinal injuries, fractures and dislocation)	322412 (82.8)
Head injuries	62509 (16.0)
Skull fracture %	6827 (1.8)
Intracranial injuries %	57042 (14.6)
Spinal injuries	13526 (3.5)
Vertebral fracture %	12845 (3.3)
Spinal cord lesion without evidence of bone injury=%	789 (0.2)
Upper limb fracture =%	100855 (25.9)
Lower limb fracture =%	57025 (14.6)
Hip fracture =%	84956 (21.8)
Trunk fracture =%	16114 (4.1)
Dislocation =%	7724 (2.0)

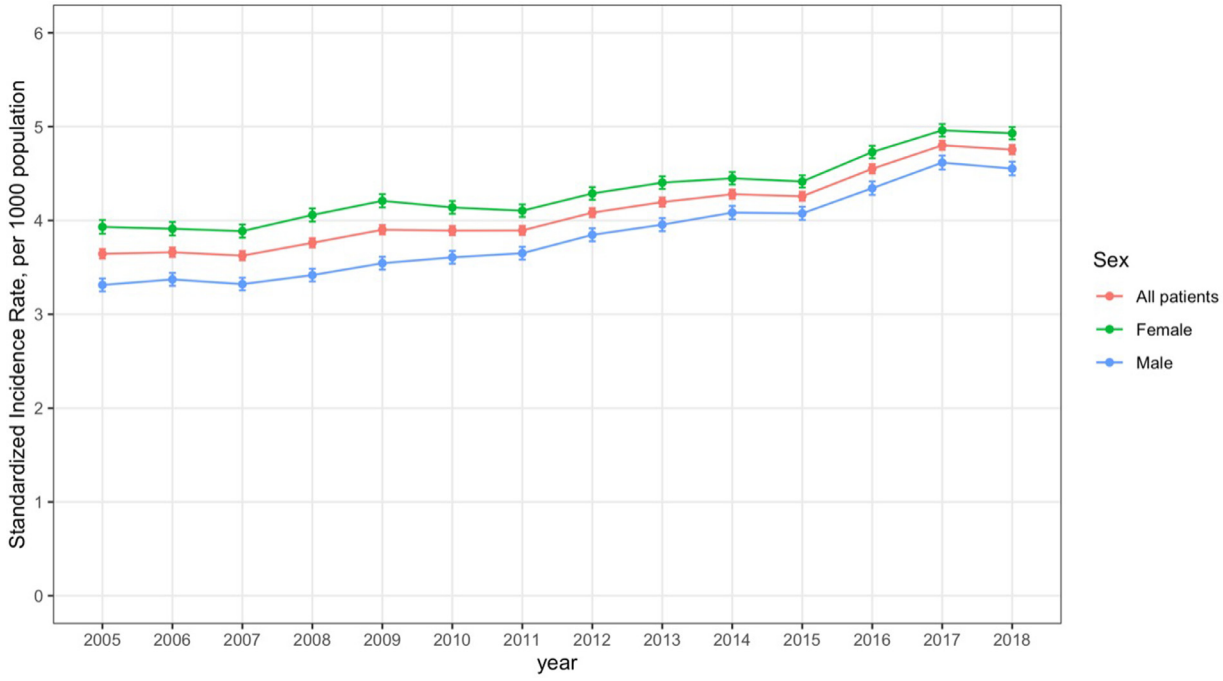

Figure 1. Secular trend of age- and sex-standardized incidence rate of patients who were admitted to the hospital with unintentional falls (per 1000 population)

trend was observed in both female and male population. In subgroup analysis by age, such decreasing trend was only observed in some (20-29, 30-39, 50-59, and 60+) but not all (10-19, and 40-49) subgroups (Table 5).

4. Discussion

In this large population study with a long study period of over 10 years involving 336,439 patients who were hospitalized due to fall injuries, we provided a comprehensive update on the incidence of fall-related hospitalization and the related outcomes. We showed that 33.7% of the fall-related hospitalization occurred in people aged under 60, while the secular trend of fall-related hospitalization increased continuously in terms of both total number and incidence rate. Although there was a decreasing trend of median LOS per patient, the total LOS in all fall patients were increased by 67.5% from 2005 to 2018. A significant decreased trend was observed for the 1-year all-cause mortality after falls.

We are the first in Hong Kong to report the increasing secular trend of fall-related hospitalization rate in the Hong Kong population that includes both younger and older age groups. Two other studies on fall-related injuries were conducted in Hong Kong. However, one only investigated the trend in fall-related hospitalization among patients aged 0-19 [20] while the other one was a cross-sectional study that interviewed 1,500 community-dwelling elderly aged 65 or above on their incidence of falls. [21] There were in-

Table 2
Incidence rates of falls by age and sex, 2005 – 2018, per 1000 person-years

Age group	Sex	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	P-value for trend	AAPC (95% CI)
10-19	Both	2.35	2.33	2.17	2.05	2.13	2.11	2.18	2.38	2.41	2.53	2.60	2.40	2.82	2.78	0.0015	1.2 (0.0, 2.4)
	Female	0.88	0.91	0.92	0.83	0.79	0.90	0.90	1.11	1.08	1.23	1.17	1.13	1.30	1.31	<.0001	3.2 (1.1, 5.4)
	Male	3.76	3.68	3.35	3.20	3.40	3.25	3.40	3.58	3.66	3.76	3.95	3.61	4.25	4.16	0.013	0.7 (-0.5, 1.9)
20-29	Both	1.15	1.13	1.11	0.99	1.10	1.16	1.12	1.17	1.17	1.17	1.21	1.18	1.29	1.14	0.030	0.8 (0.1, 1.5)
	Female	0.54	0.50	0.55	0.45	0.50	0.59	0.58	0.60	0.63	0.61	0.65	0.61	0.79	0.66	0.00049	2.7 (1.5, 4.0)
	Male	1.86	1.86	1.76	1.63	1.81	1.84	1.75	1.84	1.80	1.82	1.85	1.82	1.85	1.67	0.88	0.0 (-0.6, 0.6)
30-39	Both	1.08	1.12	1.10	1.08	1.14	1.18	1.21	1.30	1.33	1.36	1.24	1.29	1.27	1.30	0.00016	1.1 (-0.4, 2.8)
	Female	0.58	0.57	0.54	0.55	0.62	0.65	0.63	0.69	0.73	0.71	0.70	0.74	0.74	0.74	<.0001	1.9 (0.2, 3.7)
	Male	1.73	1.84	1.86	1.79	1.86	1.93	2.02	2.18	2.21	2.32	2.05	2.10	2.05	2.14	0.0010	1.4 (0.4, 2.4)
40-49	Both	1.40	1.50	1.37	1.42	1.45	1.48	1.52	1.55	1.70	1.72	1.85	1.96	1.92	1.87	<.0001	2.2 (0.3, 4.1)
	Female	0.87	0.97	0.86	0.93	0.96	1.04	1.01	1.17	1.21	1.17	1.29	1.36	1.34	1.30	<.0001	3.7 (2.9, 4.5)
	Male	1.97	2.08	1.94	1.99	2.03	2.03	2.18	2.05	2.36	2.45	2.60	2.79	2.76	2.68	<.0001	2.4 (0.2, 4.6)
50-59	Both	2.41	2.39	2.29	2.44	2.52	2.60	2.61	2.94	2.99	3.00	3.00	3.28	3.37	3.44	<.0001	3.3 (2.8, 3.8)
	Female	2.49	2.41	2.18	2.45	2.53	2.70	2.61	2.98	3.07	2.97	3.05	3.42	3.49	3.63	<.0001	3.7 (3.0, 4.4)
	Male	2.33	2.38	2.40	2.42	2.50	2.51	2.60	2.90	2.90	3.04	2.95	3.13	3.24	3.23	<.0001	2.9 (2.5, 3.4)
≥=60	Both	11.55	11.55	11.70	12.35	12.76	12.53	12.45	12.83	13.17	13.49	13.29	14.49	15.40	15.24	<.0001	2.3 (1.8, 2.8)
	Female	15.45	15.34	15.51	16.19	16.79	16.07	16.00	16.28	16.72	17.06	16.72	17.94	18.87	18.69	<.0001	1.6 (1.1, 2.0)
	Male	7.26	7.37	7.48	8.12	8.32	8.63	8.54	9.01	9.25	9.53	9.49	10.66	11.57	11.42	<.0001	3.8 (3.2, 4.4)
Overall	Both	3.31	3.36	3.38	3.55	3.76	3.84	3.92	4.18	4.39	4.57	4.64	5.09	5.50	5.57	<.0001	4.3 (3.6, 5.0)
	Female	3.47	3.50	3.55	3.77	4.02	4.07	4.13	4.41	4.65	4.83	4.92	5.42	5.84	5.95	<.0001	4.5 (4.1, 4.9)
	Male	3.13	3.20	3.18	3.29	3.46	3.57	3.67	3.91	4.07	4.27	4.31	4.71	5.11	5.12	<.0001	3.9 (3.0, 4.8)

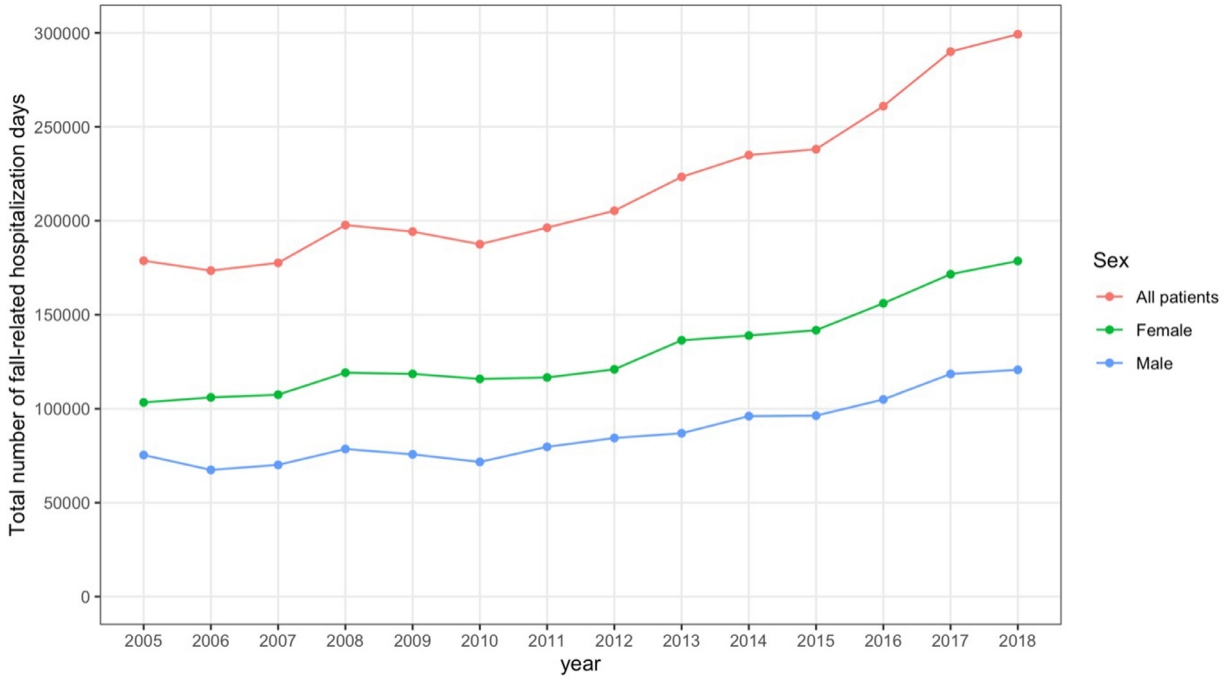

Figure 2. Secular trend of the total number of fall-related hospitalization days among fall patients, 2005-2018

deed no similar studies that focused on the secular trend of falls among both geriatric and non-geriatric population in Hong Kong. However, the observed elevation in incidence of falls in the older population was also observed in other developed countries with similar population structure, suggesting the elevation in incidence of falls among the geriatric population may be a common global health concern. For instance, a population-based study in Netherlands demonstrated an overall increase in incidence of fall-related hospital admissions among people aged 65 or above from 1981 through 2008, with an APC of 1.3% in men and 0.7% in women. [22] Another study in the United States showed an increase in fall-related hospitalization rate among patients aged 65 or above, with a slightly higher annual increase of 4% (95% CI 2.9% to 5.0%) from 2001 to 2012. As observed in the current population-based study in Hong Kong, the incidence rate of fall-related hospitalization in people aged 60 or above also increased significantly from 2005 to 2018 (AAPC 2.3% [95% CI 1.8% to 2.8%]). However, the estimated incidence rate of fall-related hospitalization could be affected by the differences in the version of ICD, public health policies, population structures, resource availability and coding protocol between different countries. While all forementioned studies demonstrated an elevation in the incidence rate of falls, the actual estimate of incidence rate should be interpreted carefully. In addition to the increasing incidence of fall injuries in the older pop-

Table 3
Incidence rate of falls with severe clinical outcome per 1000 population, by age group and sex, per 1000 person-years

Age group	Sex	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	P-value for trend	AAPC (95% CI)
10-19	Both	2.21	2.17	1.98	1.88	1.95	1.87	1.98	2.16	2.17	2.30	2.35	2.19	2.52	2.45	0.0088	0.8 (-0.5, 2.1)
	Female	0.79	0.83	0.82	0.71	0.68	0.74	0.76	0.95	0.92	1.07	0.98	0.95	1.09	1.06	0.00064	2.5 (0.0, 5.1)
	Male	3.57	3.46	3.08	2.98	3.16	2.93	3.12	3.31	3.34	3.46	3.64	3.35	3.88	3.77	0.042	0.4 (-0.9, 1.7)
20-29	Both	1.00	0.96	0.92	0.83	0.91	0.92	0.93	0.95	0.97	0.97	1.01	0.98	1.07	0.94	0.13	0.2 (-1.1, 1.5)
	Female	0.44	0.42	0.44	0.35	0.39	0.39	0.44	0.44	0.49	0.49	0.51	0.48	0.62	0.49	0.0028	2.6 (1.1, 4.1)
	Male	1.65	1.60	1.50	1.40	1.52	1.55	1.50	1.56	1.54	1.52	1.59	1.54	1.56	1.43	0.42	-0.2 (-0.8, 0.4)
30-39	Both	0.94	0.94	0.93	0.92	0.93	0.98	1.00	1.08	1.10	1.14	1.04	1.06	1.05	1.08	0.00038	0.9 (-0.7, 2.6)
	Female	0.49	0.46	0.43	0.46	0.47	0.51	0.49	0.55	0.58	0.57	0.58	0.58	0.59	0.59	<.0001	1.4 (-0.4, 3.2)
	Male	1.52	1.56	1.59	1.55	1.56	1.63	1.72	1.84	1.85	1.98	1.73	1.79	1.74	1.82	0.0013	1.6 (0.8, 2.4)
40-49	Both	1.24	1.28	1.18	1.24	1.24	1.23	1.28	1.31	1.46	1.48	1.60	1.63	1.61	1.54	<.0001	1.7 (-0.1, 3.4)
	Female	0.77	0.81	0.73	0.80	0.82	0.84	0.81	0.94	1.02	0.98	1.12	1.15	1.10	1.05	<.0001	2.4 (-0.1, 5.0)
	Male	1.76	1.81	1.68	1.74	1.74	1.71	1.89	1.78	2.04	2.13	2.25	2.30	2.34	2.24	<.0001	1.9 (-0.4, 4.2)
50-59	Both	2.16	2.12	2.00	2.13	2.13	2.23	2.23	2.56	2.58	2.58	2.61	2.81	2.81	2.87	<.0001	3.0 (2.4, 3.5)
	Female	2.24	2.14	1.92	2.13	2.18	2.34	2.26	2.62	2.69	2.58	2.69	2.96	3.00	3.06	<.0001	3.4 (2.7, 4.2)
	Male	2.08	2.09	2.08	2.12	2.09	2.11	2.20	2.49	2.46	2.58	2.53	2.64	2.60	2.64	<.0001	1.9 (0.9, 2.8)
≥=60	Both	10.16	9.96	10.01	10.40	10.49	10.21	10.20	10.54	11.05	11.17	11.03	11.21	11.51	11.22	<.0001	1.1 (0.8, 1.4)
	Female	13.68	13.31	13.43	13.79	13.88	13.29	13.29	13.58	14.22	14.34	14.10	14.33	14.67	14.31	0.0011	0.7 (0.4, 1.0)
	Male	6.31	6.27	6.22	6.66	6.77	6.82	6.80	7.19	7.55	7.66	7.65	7.75	8.01	7.79	<.0001	2.0 (1.6, 2.4)
Overall	Both	2.94	2.92	2.91	3.03	3.13	3.17	3.26	3.49	3.71	3.84	3.91	4.06	4.26	4.26	<.0001	3.1 (2.1, 4.1)
	Female	3.07	3.03	3.07	3.22	3.33	3.36	3.43	3.69	3.95	4.07	4.17	4.38	4.61	4.62	<.0001	3.8 (3.4, 4.1)
	Male	2.79	2.79	2.73	2.82	2.91	2.94	3.06	3.26	3.42	3.56	3.60	3.68	3.85	3.82	<.0001	2.7 (1.4, 4.0)

Table 4
Median length of stay (LOS) of fall patients by age and sex, 2005 – 2018

Age group	Sex	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	P-value for trend
10-19	Both	1.65	1.39	1.56	1.65	1.61	1.57	1.63	1.67	1.57	1.52	1.59	1.23	1.22	1.53	0.098
	Female	1.78	1.58	1.70	1.76	1.67	1.62	1.64	1.70	1.60	1.64	1.61	1.22	1.53	1.70	0.083
	Male	1.63	1.33	1.53	1.63	1.58	1.56	1.62	1.66	1.57	1.45	1.58	1.25	1.18	1.41	0.080
20-29	Both	2.05	1.88	1.82	1.84	1.85	1.81	1.83	1.84	1.74	1.72	1.78	1.81	1.81	1.85	0.033
	Female	1.95	1.92	1.69	1.82	1.82	1.87	1.68	1.79	1.68	1.76	1.75	1.71	1.69	1.84	0.060
	Male	2.09	1.87	1.92	1.86	1.91	1.80	1.88	1.85	1.78	1.71	1.78	1.83	1.87	1.85	0.025
30-39	Both	2.40	2.49	2.17	2.43	2.11	2.14	2.01	1.93	1.99	1.91	1.96	1.93	2.00	1.84	<.0001
	Female	1.89	2.49	1.77	2.56	1.94	1.99	2.11	1.81	1.99	1.83	1.92	1.88	1.93	1.84	0.12
	Male	2.67	2.48	2.50	2.39	2.20	2.25	1.96	1.97	1.99	1.96	1.97	1.96	2.03	1.84	<.0001
40-49	Both	2.91	2.92	2.92	2.93	2.74	2.64	2.73	2.46	2.29	2.19	2.13	2.14	2.04	2.10	<.0001
	Female	2.66	2.75	2.82	2.93	2.64	2.55	2.65	2.19	2.22	2.12	2.07	2.16	2.01	2.20	<.0001
	Male	2.99	3.05	2.98	2.93	2.79	2.66	2.76	2.65	2.35	2.32	2.19	2.14	2.05	2.05	<.0001
50-59	Both	3.47	3.12	3.19	3.31	3.02	2.91	2.85	2.72	2.63	2.69	2.57	2.49	2.29	2.55	<.0001
	Female	3.16	3.03	3.05	2.98	3.06	2.81	2.75	2.34	2.48	2.24	2.24	2.22	2.13	2.25	<.0001
	Male	3.69	3.45	3.46	3.78	2.97	3.05	2.91	2.94	2.72	2.84	2.78	2.74	2.60	2.72	<.0001
≥=60	Both	7.21	7.13	6.83	6.87	5.94	5.70	5.35	5.09	5.20	5.02	4.99	5.04	4.91	4.78	<.0001
	Female	7.13	7.23	6.90	7.00	6.03	5.82	5.57	5.17	5.48	5.05	5.03	5.08	4.94	4.85	<.0001
	Male	7.62	6.88	6.60	6.53	5.71	5.24	5.09	4.96	4.98	4.96	4.88	4.93	4.82	4.58	<.0001
Overall	Both	4.90	4.79	4.77	4.85	4.27	4.08	3.97	3.86	3.88	3.85	3.82	3.91	3.83	3.79	<.0001
	Female	5.91	5.87	5.74	5.84	5.10	4.85	4.72	4.31	4.58	4.21	4.13	4.23	4.09	4.03	<.0001
	Male	3.70	3.56	3.61	3.74	3.23	3.32	3.14	3.09	3.04	3.10	3.07	3.39	3.24	3.16	0.0047

ulation as observed in many countries, our study further demonstrated that such situation has not been improved even though a global fall prevention campaign has been launched. This suggested that the global campaign was insufficient to lower the risk of falls in Hong Kong. This could be due to the presence of characteristics or risk factors specific in the Hong Kong population that put the local population at risk, which was not addressed by the fall prevention campaign launched globally. Local interventions may potentially fill the gap of existing global fall prevention campaign. Moreover, we also showed that incidence of fall-related hospitalization is also increasing in the younger population in Hong Kong for the first time.

Although studies have been conducted extensively on falls in the elderly, falls in people aged below 60 has been a neglected topic. Through literature search, 11 studies describing the epidemiology of falls in people aged below 60 were identified. However, most of these were either conducted in earlier years, or presented with a restricted analysis of the data (for example, secular trend of falls was unavailable, and they did not compare the number of falls between the younger and the older population). The two only studies that compared the secular trend of fall incidence among younger and older age groups were conducted before 2009. [23,24] The first study showed the trend of hospitalized falls in people aged <15 and between 15 and 64, but no detailed estimates of the secular trend in each age group were reported. [23] The second study evaluated the younger and older population as a single group (aged 17-64) and reported an increasing trend of hospitalized falls. [24] Unfortunately, we were only able to identify studies that were written in English language with an English title. Although there was a lack of research paper that detailly discussed the secular trend of falls among the younger population, the U.S. Web-based Injury Statistics Query and Reporting System (WISQARS), reported the estimated crude incidence rate of falls among different age groups. [25] Upon analysis using the data provided by WISQARS, a similar increase in incidence of non-fatal falls among people aged 50 or above was observed. However, the data

Table 5
1-year mortality rate of fall patients, by age group and sex, per 1000 cases (n=330,629)

Age group [a]	Sex	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	P-value for trend	AAPC (95% CI) [b]
10-19	Both	1.05	0	0.57	0.61	1.22	0.63	2.52	1.81	0	0	0.64	1.44	0.64	0.66	0.96	NA
	Female	5.65	0	2.72	0	0	3.03	3.12	0	0	0	0	0	0	0	0.039	NA
	Male	0	0	0	0.76	1.49	0	2.37	2.35	0	0	0.83	1.88	0.83	0.86	0.28	NA
20-29	Both	4.68	8.56	7.63	5.34	6.66	4.48	6.54	5.41	5.49	1.85	2.67	0.94	2.59	0.99	0.00041	-9.4 (-14.6, -3.9)
	Female	15.04	3.95	10.49	0	7.55	3.27	9.84	6.45	12.54	3.28	0	0	0	3.26	0.053	NA
	Male	1.25	10.03	6.55	7.10	6.36	4.93	5.23	5.01	2.58	1.29	3.75	1.32	3.86	0	0.018	NA
30-39	Both	10.03	12.27	14.11	8.61	4.09	6.32	9.32	7.81	3.47	3.40	4.43	4.27	4.33	4.25	0.0012	-9.2 (-13.1, -5.2)
	Female	10.93	14.04	5.90	11.56	7.71	7.33	10.08	2.25	0	0	4.37	4.07	4.04	4.02	0.0040	NA
	Male	9.64	11.55	17.32	7.36	2.40	5.84	8.99	10.37	5.14	4.94	4.46	4.38	4.49	4.37	0.017	-8.7 (-13.7, -3.4)
40-49	Both	16.70	11.50	9.80	9.59	15.73	16.81	10.12	14.50	12.00	9.97	7.01	9.52	12.17	15.67	0.51	-1.1 (-4.6, 2.6)
	Female	8.52	12.07	10.15	7.97	10.85	12.89	3.01	14.42	8.92	9.32	6.09	10.42	11.81	13.37	0.67	0.9 (-3.3, 5.3)
	Male	20.68	11.20	9.62	10.48	18.50	19.32	14.36	14.56	14.13	10.40	7.65	8.89	12.43	17.32	0.39	-1.9 (-6.0, 2.4)
50-59	Both	23.86	26.49	28.14	33.03	26.28	24.98	18.65	22.23	22.46	21.89	20.90	23.70	16.87	15.74	0.0030	-3.6 (-5.5, -1.6)
	Female	13.13	16.57	18.29	25.20	12.85	16.52	16.43	16.99	14.84	13.22	13.21	15.00	14.35	6.80	0.060	-3.6 (-6.9, -0.2)
	Male	35.43	36.59	37.20	41.11	40.32	34.38	21.00	27.90	31.06	31.14	29.75	34.56	19.98	27.56	0.016	-2.9 (-5.3, -0.5)
≥=60	Both	139.83	138.34	149.11	150.75	146.96	137.47	139.99	132.11	135.68	136.71	129.27	128.51	127.70	119.17	0.00034	-1.0 (-2.0, 0.1)
	Female	110.76	108.17	120.71	120.00	122.21	111.12	110.83	103.50	103.49	107.27	97.15	96.31	96.71	89.86	0.00033	-1.4 (-2.7, -0.0)
	Male	202.86	203.52	208.98	214.02	198.65	187.58	195.56	184.67	194.44	189.15	185.27	181.92	178.41	167.15	<.0001	-1.5 (-1.9, -1.0)
Overall	Both	83.65	83.42	93.13	97.36	95.57	89.77	90.42	85.74	88.32	89.66	85.15	87.90	88.32	83.58	0.39	0.2 (-1.0, 1.4)
	Female	83.36	81.85	92.93	93.66	94.64	85.00	84.91	78.14	77.93	81.06	73.09	73.54	74.71	69.10	0.0011	-1.3 (-2.8, 0.3)
	Male	83.98	85.20	93.36	101.80	96.71	95.56	97.02	94.92	101.03	100.02	99.80	105.63	105.22	101.84	0.00033	1.3 (0.7, 1.8)

[a] 1-year mortality rate were missing in specific sex and age groups due to insufficient deaths
[b] Average annual percentage change (AAPC) of specific age group and sex were not available due to insufficient datapoint.

also showed significant reduction in incidence of falls among people aged 0 – 44 (Supplementary Table 1). The discrepancy in the trend of incidence of falls among non-geriatric population found in our study and WISQARS could be due to the difference in coding practice or inclusion criteria. Notably, our study showed that approximately one-third of falls were indeed contributed by the younger population. Although it could be attributed to the population structure, it highlighted that non-geriatric fallers also made-up a substantial proportion of the fall population, especially when Hong Kong is considered a rapidly ageing society with people aged 60 or above accounting for >24% of the total population. [14] Further studies should be conducted on younger fallers. For instance, to compare their comorbidity pattern with the geriatric population, to investigate potential reasons behind the increasing incidence of falls among young population, and to identify risk factors specifically associated with the young fallers.

Reasons for increasing propensity of falls have been well described in older people, including sarcopenia, side effect of drugs for treating diabetes, hypertension, psychiatric disorders [26,27] etc. However, the reasons for increasing risk of falls in the younger population is less studied. This could be the same as those for the older population, although to a lesser extent. Engagements in more dangerous exercises and activities could also be important factors associated with increased risk of falls in the younger population.

In general, increase in fall-related hospitalization could be due to the improved awareness on the consequences of fall-related injuries by the patients, hence encouraging their health-seeking behavior following a fall. Although there was a continuous increase in the incidence of fall-related hospitalization (including fall-related severe injuries), the median LOS decreased over time. We further looked at the percentage of fall patients having severe injuries upon hospital admission, we observed that there was a decrease in percentage of fall episodes admitted with head or spinal injuries, fractures or dislocations from 88.7% in 2005 to 76.4% in 2018 ($p<.0001$). Thus, the concurrent increase in total incidence of fall-related hospitalization and the continuous reduction in proportion of fall patients admitted with severe fall injuries might be partly contributed by the increased awareness of the consequences of falls, hence enhancing their health seeking behaviors even after minor falls. As a result, falls with mild injuries were also sent to the hospitals. Further studies are required to support such hypothesis. Similarly, the increase in overall incidence may partly be explained by the greater availability of hospital beds. [28,29] Notably, the incidence of severe fall-related injuries and total LOS were indeed increasing rapidly, which is less affected by the availability of hospital beds. In addition, based on the report “Health Facts of Hong Kong” released by the Department of Health of the HKSAR government, the number of hospital beds in hospitals under the Hospital Authority has increased from 26,981 per day in 2011 (earliest data available) to 28,329 per day in 2018 (+5.0%).[28,29] The proportion of in-patient bed-days occupied by fall patients therefore increased from 1.99% in 2011 to 2.89% in 2018. The rapid elevation in the rate of fall-related hospitalization occupancy suggested that it indeed imposed a significant burden on the public healthcare system in Hong Kong, particularly due to its highly subsidized nature, where patients are only required to pay a flat rate of HKD$100 per day (~USD$12.8) for in-patient hospitalization, while the average actual cost of hospitalization per day is $4,910 (~USD$629.5). [30]

In the study, 1-year all-cause mortality after falls instead of mortality directly caused by falls was discussed due to the underreporting of falls as cause of death due to coding. Such bias in cause of death classification was indeed common among different countries. [31] Furthermore, frailty, immobility and injuries (e.g. hip fracture) resulted from falls are associated with a number of complications, including pneumonia, urinary tract infection and stroke. [32,33] Investigation in the change in 1-year all-cause mortality post-falls would shed lights on the prognosis, as well as its associated clinical implications. For instance, how improvement in post-fall care could be beneficial to fall patients. On the other hand, falls per se could also be a marker of the presence of other health conditions. Thus, clinicians should pay attention to patients with falls, as management of the fall-related risk factors may reduce subsequent mortality. Nevertheless, we also acknowledge that

all-cause mortality also took into account of deaths that are were not caused directly or indirectly by falls.

There are clinical implications of our findings. First, this study shed lights on the fall-related hospitalization among the adolescents, young and middle-aged adults, which is a neglected area. Although fall prevention programs and clinics are currently available in Hong Kong, most of them are targeting the elderly population. For instance, patients admitted to the fall clinics were limited to geriatric patients with history of falls. Opportunistic screening for the risk of falls, related physical examination and referral services available are all targeted for elderly aged 65 or above. As our study indicated incidence was increasing continuously in both the younger and elderly population, the fall prevention measures should be further expanded to tackle these issues. Furthermore, there has been a lack of research in terms of falls among the non-geriatric population in Hong Kong. Only one study on fall-related hospitalization was conducted in non-elderly patients in Hong Kong, involving patients aged 0-19. [20] While research and intervention on falls among younger adults were minimal, the potential impact of fall-related injuries among them should not be overlooked. In fact, falls during non-geriatric years might also lead to detrimental consequences. Compared to 17.77% of patients aged 60 or above with head injuries, 12.65% of patients aged between 10 – 59 were also diagnosed with head injuries upon hospital admission (Supplementary table 5). Study has shown significant reduction in health and level of functioning among patients aged 25 – 60 years old 15 months after admitted to hospital following unintentional falls. [34] Injuries of lower extremity were also associated with a higher risk of declination in patients' health and function. [34] In line with these findings, lower limb fractures were found in 25.98% of patients aged between 10-59 within our cohort (Supplementary table 5). Nonetheless, falls among the younger patients, who are usually healthy and productive, may result in lifelong disabilities that significantly reduce their mobility, hence lowering their quality of life. [2] While many population-based studies on falls conducted in a number of countries focused on the geriatric population, as well as their associated risk factors, there were a lack of research attention on the fall-related injuries among the non-geriatric population. More importantly, most of the risk factors identified previously were specific to the geriatric population, which were unable to explain the increased incidence of falls among the younger population as identified in our study. This study therefore suggested future research on the risk factors and comorbidities associated with falls among adolescents and young adults are warranted. Second, this study suggested that evaluation in Hong Kong's current fall prevention program is needed. While fall prevention programs were implemented in many countries around the globe, many of them included multifactorial interventions to improve individuals' physical function and reduce their corresponding risk of fall. In Hong Kong, the first fall prevention clinic was established by the Hospital Authority in 2009. Since then, progressively more resources were put into public education and fall prevention clinics. However, our study showed continuous elevation in the incidence of fall-related hospitalization in Hong Kong although more efforts were made in reducing the risk of falls within the community. Moreover, despite the founding of fall clinic targeting the geriatric population, no joinpoints were identified in the trend analysis of fall incidence in people aged 60 or above, suggesting more effort should be put into reducing the incidence of fall in Hong Kong. Although a recent study showed no significant difference in the fall-prevention efficacy between multifactorial interventions and enhanced usual care, [19] many other studies had demonstrated that multifactorial fall-prevention interventions were promising. [35] Currently, there is no consensus on which fall-prevention intervention is more efficient, and it is likely to be population-specific. It is therefore essential for different countries to develop their own population-based fall-prevention program. Its effectiveness on reducing the incidence of falls should also be revisited regularly, which is lacking in Hong Kong at present.

The strengths of this study include long study period, large sample size, and population-base high-quality data. This study considered not only the incidence of fall-related hospitalization, but also evaluated the associated clinical outcomes (e.g. severe injuries, LOS, and 1-year all-cause mortality), thus allowing a comprehensive analysis of the falls and revealing the burden brought to the public healthcare system separately. However, there are limitations. First, it only focused on patients who were admitted to hospital after falls. Those who experienced less severe falls that did not require hospitalization or seek medical care in outpatient clinics were not included in the cohort. Thus, the incidence of falls, especially among the younger population whose injuries are often minor, as well as the actual burden associated with fall-related injuries, might be underestimated. Secondly, patients that were not admitted through the A&E departments of public hospitals, for instance those who experienced falls within the hospitals or those admitted through the A&E departments of private hospitals, were not captured. As the current study focused on the incidence of falls in the community, falls within the hospital were not covered. Nevertheless, we expect the number of falls within the hospitals would be minimal when compared to those in the community. While fall-related injuries that lead to hospitalizations would usually require emergency services through the A&E departments, we estimate that number of fall patients admitted to private hospitals might be comparatively small, as only two out of the 12 private hospitals in Hong Kong (not captured by CDARS) provide A&E services. Even fall patients admitted to the hospitals from other locations, including those transferred from private hospitals, would have been captured in our study, as long as they had registered in the A&E departments of any of the 43 public hospitals in Hong Kong. In general, CDARS was able to capture $>$84% of fall-related hospitalization. [8] As this might underestimate, instead of overestimate, the actual population-based fall-related hospitalization rate in Hong Kong, the incidence of falls, thus the actual impact of falls in people aged $\geq$10 would have been greater than estimated in our study, imposing even heavier burden on public healthcare services. Thirdly, there could be misclassification of diagnosis coding from which our cohort was based on. For instance, non-fall patients might have been coded as having falls. However, a previous study has demonstrated a good positive predictive value ($>$95%) of diagnostic coding in CDARS. [36] We believe that this study has provided important insights on the current trend of fall incidence among population of all ages and the associated burden of falls on Hong Kong's public healthcare system. Fourthly, detailed causes of fall-related hospitalization, often require detailed interview, were not included in this study. Since there have been changes during the studied time period, the underlying causes of increased trend of incidence are unknown. Moreover, since falls itself could indicate the presence of other health conditions, LOS and all-cause mortality of the fall patients could potentially be over-interpreted. Prolonged LOS and subsequent mortality could be due to both the consequences of falls itself and the comorbidities with falls. The results on LOS and all-cause mortality should therefore be interpreted with great caution.

To conclude, a significant increase in incidence of fall-related hospitalization across all age and sex during the study period of 2005 – 2018 was observed in the Hong Kong population. Current evidence suggested that such elevation in incidence of fall-related hospitalization could be contributed by genuine increase in fall injuries, improved awareness of fall-related consequences, and elevated hospital admission of fall patients with mild injuries. Although the reduction in median LOS over the past 14 years was statistically significant, the decrease was modest and it might not

be clinically significant. Thus, the burden of falls brought to the healthcare system remained huge. Together with the continuous elevation in total fall-related hospitalized bed-days, falls inevitably imposed extra burden to the already over-stretched public healthcare system. Since one-third of the fall-related hospitalization occurred in people aged under 60, multifactorial interventions in fall prevention should not be limited to the geriatric population only, but also extend to the younger people. Further research on the reasons and associated risk factors among young fallers, as well as the efficacy of Hong Kong fall prevention interventions should be conducted.

Contributors

CTLT and CLC contributed to the conceptualization of research question and study design. CTLT was responsible for formal data analysis and production of first draft of the manuscript. CWS and CLC contributed to validation and verification of data. All authors contributed to the interpretation of results and writing of the manuscript.

Data sharing

We are unable to share the individual data used in the study. The Clinical Data Analysis and Reporting System (CDARS) is directly managed by the Hong Kong Hospital Authority. CDARS data can be accessed via HA Data Sharing Portal for research purpose. The related information can be found online (https://www3.ha.org.hk/data).

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Declaration of Competing interest

We declare no conflicts of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.lanwpc.2021.100183.

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